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AUTHOR Filer, Herb; Broste, Dale
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ABSTRACT

This lesson was developed for a course in sludge treatment and disposal. The lesson describes the Porteous heat treatment method of sludge conditioning and compares that system to the Zimpro wet air oxidation process. The theory of heat treatment, system of components and functions, and concepts of operation are addressed in the lesson. The instructor's manual contains a brief description of the lesson, estimated time, instructional materials list, suggested sequence of presentation, required reading list, reference reading list, objectives, lecture outline, narrative of the slide/tape program used with the lesson, and student worksheet (with answers): The student workbook contains objectives, plant flow diagrams, glossary, discussion of heat treatment, references, and worksheet. (Author/JN)

XT-153 (HT.)

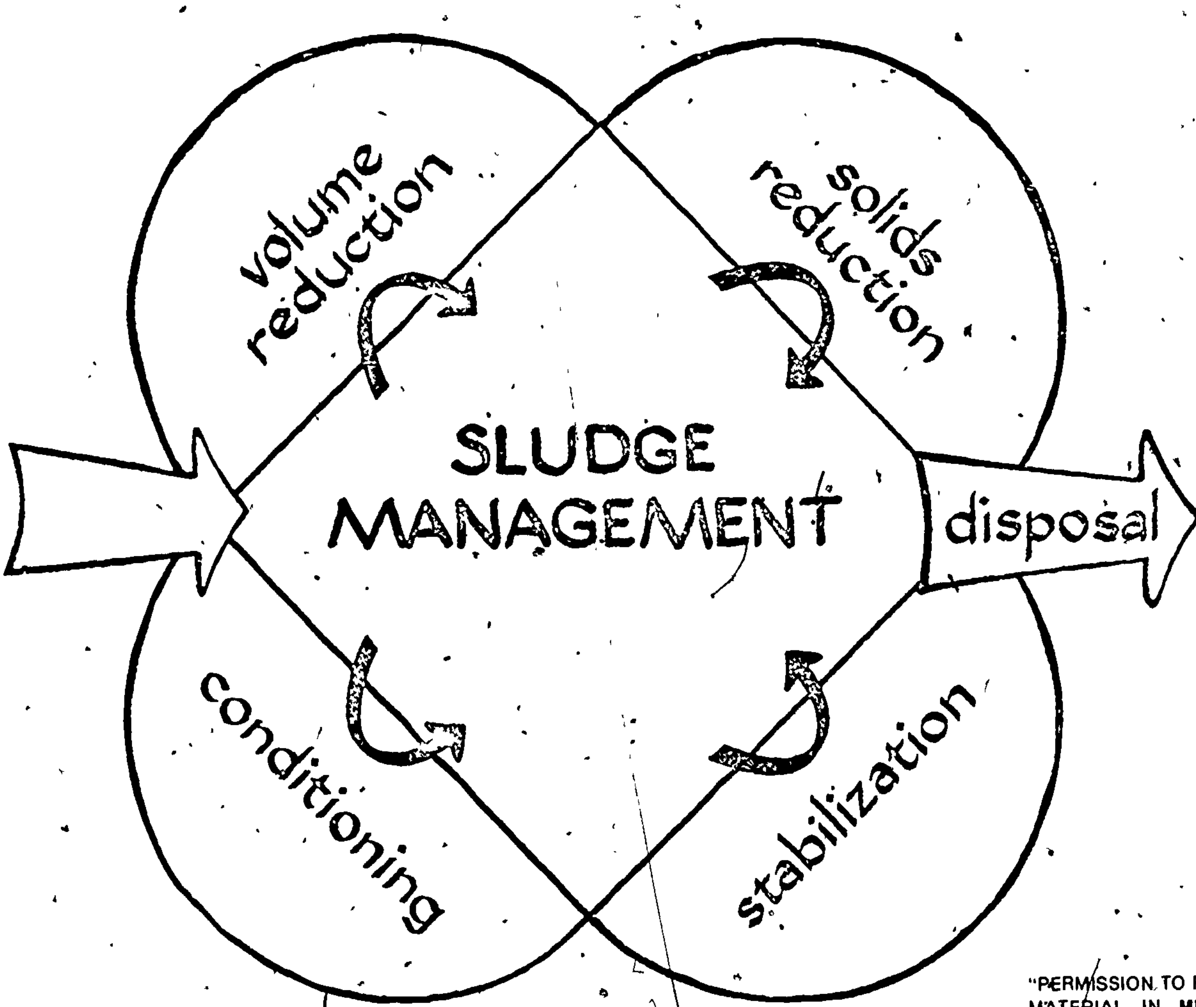
SLUDGE TREATMENT

and

DISPOSAL

COURSE # 166

HEAT TREATMENT



INSTRUCTOR'S GUIDE

Prepared by
Linn-Benton Community College
and
Envirotech Operating Services

HEAT TREATMENT

Written by:
Herb Filer
Dale Broste
Envirotech Operating Services

Edited by:
John Carnegie, PhD.
Linn-Benton Community College

Instructional Design:
Priscilla Hardin
Corvallis, Oregon

Technical Consultant:
Envirotech Operating Services
San Mateo, California

Project Director:
Paul H. Klopping
Linn-Benton Community College
Albany, Oregon

Project Officer:
Lynn S. Marshall
United States Environmental Protection Agency
National Training and Operational Technology Center
Cincinnati, Ohio

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HEAT TREATMENT

CONTENTS

HEAT TREATMENT

Lesson Description

This lesson describes the Porteous Heat Treatment method of sludge conditioning and compares that system to the Zimpro wet air oxidation process. The theory of heat treatment, the system components and functions, and the concepts of operation are all covered in this lesson.

Estimated Time

Student Preview of Objectives	5 minutes
Presentation of Slide/Tape Program	15 minutes
Worksheet	10 minutes
Correct Worksheet and discussion	10 minutes

Instructional Materials List

1. Student text "Heat Treatment"
2. Slide set "Heat Treatment"
3. Diagrams and pictures of process
4. Slide projector and screen

Suggested Sequence of Presentation

1. Assign students to read objectives in class.
2. Lecture using slide/tape program, diagrams and pictures.
3. Discussion.
4. Assign worksheet.
5. Correct worksheet and discuss questions.

Required Reading

Student Text "Heat Treatment", EPA Course #166

Reference Reading

<u>Process Design Manual for Sludge Treatment and Disposal</u>, U.S. EPA, September, 1979, EPA 625/1-79-001.

HEAT TREATMENT

OBJECTIVES

Upon completion of this lesson, the student should be able to do the following:

1. Recall that the first full size, continuous flow systems were placed in operation in 1964.

2. Recall that syneresis and hydrolysis play a large role in releasing the water from sludge.

3. Be able to identify each of the following components of the heat treatment system and place them in the proper operational sequence.

    a) Blend tank

    b) Grinder

    c) High pressure pump

    d) Heat exchanger

    e) Reactor

    f) Orifice plates

    g) Decant tank

    h) Flow meter

    i) Level control valve

4. Recall that 85% of the heat necessary for operation comes from the heat exchanger.

5. Describe the purpose of the level control valve.

6. Describe the purpose of the orifice plates.

7. Recall the purpose of the deaerator.

8. Recall the purpose of the reactor off gas system.

9. Describe what happens in the reactor.

10. Be able to recall that heat treated sludge is dewaterable to 40% solids.

11. Describe safety precautions in the operation of a heat-treat system.

12. Be able to state three differences between the Porteous and Zimpro systems.

HEAT TREATMENT

LECTURE OUTLINE

I. History

A. Early experiments

1. In late 1800's, an experiment was conducted to manufacture briquettes from liquid peat using a batch process.
2. These experiments proved to be unsuccessful.
3. Sludge experiments began about 1911.

B. Porteous Process

1. In 1930 Porteous began his work.
2. First patents taken out in 1932.
3. Four plants built between 1932-1953.
4. First full-scale continuous flow plant built in 1964.

II. Process Theory

A. Syneresis

1. Syneresis is the process of collecting together of solids in sludge molecules.
2. Direct steam injection used to rupture sludge molecules, releasing bound water.
3. Indirect heat, such as heating coil, is ineffective.
4. Sludge molecules collide aiding in process.

B. Hydrolysis

1. Long, 30 to 45 minutes, detention time allows solid particles to give up their waters of hydration.
2. Water molecules that are electrically connected to the sludge.

C. Coalescence

1. Protein cells are broken down, releasing water resulting in coalescence of the particles.

D. Solubilization

1. Up to 30% of the solids can be solubilized.

E. Settleability

1. Settleability is increased to a very high degree.

III. Process Flow

A. Two popular systems in use.

1. Porteous process using live steam injection at high temperature and pressures.
2. Wet oxidation using high pressure air and live steam injection.

B. The Porteous process will be described in this module.

1. Normally employs a sludge to water to sludge heat exchange.
2. Continuous flow process.
3. System flow path.
    a. Blend Tank
    b. Grinder
    c. High Pressure Pump
    d. Flow Meter
    e. Heat up side of Heat Exchanger
    f. Reactor
    g. Cool down side of Heat Exchanger
    h. After cooler, if installed
    i. Orifice plates
    j. Level control valve
    k. Decant tank
    l. Necessary valves and piping.

IV. System Components

A. Blend Tank

1. Large tank used to blend the various plant sludges.
2. Equipped with a mixing device.
3. Serves as short-time storage.

B. Grinder

1. Reduces particle size to about 1/4".
2. Has fixed teeth and rotating cutter.

C. High Pressure Pump

1. Two types in common usage
    a. Piston
    b. Continuous cavity
2. Positive displacement
3. Pump capacity determines system flow rate
4. The pump is interlocked with the grinder to prevent pump from running unless the grinder is operating.

D. Flow Meter

1. Magnetic type
2. Sometimes interlocked with the High-Pressure Pump to prevent pump running without liquid.

E. Heat Exchanger

1. Three sections
   a. Heat-up section
   b. Cool-down section
   c. After-cooler section
2. All three sections placed in one "bundle".
3. Liquid coupled, tube in tube, counter flow type.
4. Sludge flows through inner tube.
5. Recirculating water flows through annulus or outer tube.
6. Provides approximately 85% of heat needed to operate.
7. Few plugging problems.
8. Sections are insulated from each other and the atmosphere.

F. Reactor

1. High pressure vessel.
2. Capacity about equal to hourly flow of the system.
3. Sludge enters through a center stand pipe.
4. Steam is injected as the sludge enters the stand pipe.
5. Sludge discharge is from two ports on the bottom of the vessel.
6. Constant level is maintained by constant flow in and out of the reactor.
7. Level detection by nuclear source (Cs^{137}) and detector.
8. Non-condensable gases vented off through the reactor off gas system.

G. Orifice Plates

1. Sized to reduce pressure in steps.
2. Maintain high pressure in heat exchanger.
3. Reduce wear on level control valve.

H. Level Control Valve

1. Electric-pneumatically operated.
2. Receives signal from Level Control System.
3. Auto or manual operation.

I. Decant Tank

1. Acts as thickener.
2. Thickens treated sludge to as high as 20% solids.
3. Overflow high in BOD.

J. Recirculating Water System

1. Multi-stage centrifugal recirculating pump.
2. Closed loop system.
3. Expansion tank takes surges caused by temperature change.
4. High pressure maintained with N_2.
5. Recovers 85% of required heat.
6. Counter flow to sludge.

K. Steam System

1. Steam is supplied by a boiler or steam generator.
2. Two types of boilers in use.
   a. Fire tube
   b. Water tube
3. Steam generator is type of boiler.
   a. Coil tube and flash chamber
   b. Fast reacting
4. Pure water supplied to boiler via a water treatment system.
5. Generator removes O_2 prior to water going to boiler.
6. High pressure pumps force water into boiler.

V. Operations

A. Goals

1. Control system at desired temperature.
2. Protect personnel and equipment.
3. Predict changes
4. Control operating costs.

B. Three control variables

1. Temperature
2. Pressure
3. Feed concentration

C. Pressure, Temperature, Affect

1. Allowable reaction time

2. Degree of cell breakdown.
3. Quality of sidestream.

D. Increase Reaction Time Effects
1. Degree of cell breakdown
2. Quality of sidestream.

E. Dewaterability increases by
1. Higher temperature and pressure
2. Longer reaction time.

F. Must balance variables to obtain best dewaterability and sidestream quality.

VI. Safety

A. High energy system.
B. Use protective clothing.
C. Open and close all valves slowly.
D. Lock out power and depressurize prior to working on system.

VII. Summary of Porteous System

A. Reduces volume of sludge to be handled.
B. Sterile product produced.
C. Renders sludge dewaterable to 40% solids.

HEAT TREATMENT

NARRATIVE

Slide #

1. This module covers sludge conditioning by heat treatment. Wet air oxidation is also discussed, as well as the theory, equipment and operation of the heat treatment process.

2. The module was written by Herb Filer and Dr. John W. Carnegie. Instructional design was done by Priscilla Hardin. Paul H. Klopping was the project manager.

3. Sludge conditioning and solids reduction are two major goals of sludge management. Heat treatment of sludge can be applied to both of these goals.

4. In either case we are concerned with removing the water associated with sludge particles. Bound water and intracellular are two types of water that make dewatering difficult.

5. Chemical conditioning by the process of coagulation releases bound water but intracellular water is not effectively released with most types of chemical conditioning.

6. Conditioning by heat treatment releases both bound water and intracellular water.

7. In heat treatment several processes take place which cause the release of water. They are rapid heating, syneresis, and hydrolysis. Individually, these reactions will only create a partial water release. But the combination of the reactions causes a near total change in the characteristics of the sludge.

8. In the heat treatment process the sludge particles are heated rapidly which causes the particles and microbial cells to rupture violently leaving pieces of sludge and cell debris and freeing intracellular water.

9. Without this rapid temperature rise the cells would essentially cook and eventually dissolve and would resemble a dissolved soup rather than descrete particles.

10. A second process that releases water is called syneresis.

11. The chemical structure of most sludge is like a gelatin. Water is trapped in this gelatin. Under high temperature and pressure the gelatin breaks down and releases bound water. This process is called syneresis.

12. The chemical process of hydrolysis also helps release water from sludge.

13. Hydrolysis occurs as large molecules in the sludge break down into smaller ones. Water molecules are destroyed as they chemically combine with the smaller molecules being broken down. The result is less water in the sludge.

14. As we have seen, heat treatment systems either condition sludge or reduce organic material. We will discuss the sludge conditioning application first and then look at the similarities and differences in the organic reduction application.

15. The main parts of the heat treatment process are the heat exchanger and the reactor.

16. The three processes involved in heat treatment (that is rapid heating, syneresis, and hydrolysis) all occur in the reactor. Sludge flows continually through the reactor with a detention time of about one hour.

17. Steam and pressure are applied to the reactor to create the conditions necessary for the three heat treatment processes. Temperatures of 350 - 400° F. and pressures of 150 - 300 pounds per square inch may by attained.

18. The heat exchanger heats the sludge before it enters the reactor and cools the sludge as it leaves the reactor.

19. A heat exchanger transfers heat energy from hot liquids to cooler liquids. Most heat exchangers use a tube-in-a-tube arrangement to bring the hot liquid closer to the cooler liquid. The heat exchanger conserves energy by using the hot treated sludge to partially heat the cool incoming sludge.

20. There are two basic types of heat exchangers. In one design, hot treated sludge transfers its heat to cool incoming sludge. In the other design, hot sludge transfers its heat to water which, in turn, transfers the heat to cool incoming sludge.

21. Although the heat exchanger and the reactor are the main parts of the heat treatment process, there are other components that make the complete system function. The upstream components are a blend tank, a sludge grinder, a high pressure pump, and a flow meter.

22. The blend tank collects sludge pumped from various parts of the plant. It usually has about a six hour holding capacity and provides for mixing of the various types of sludge. The tank also allows for fluctuations in flow, and is usually covered to reduce odor problems.

23. The sludge grinder reduces particle size to ¼ inch or less to prevent plugging of the heat exchanger tubes and damage to system valves.

24. The high pressure pump raises the sludge to operating pressure. Positive displacement pumps are needed to obtain the high pressure required by the system.

25. A magnetic coupled flow meter is used to monitor the flow of sludge through this system.

26. The down stream components are the orifice plate, level control valve, and the decant tank.

27. Sludge passes through the orifice plate after leaving the reactor and heat exchanger. The small size of the orifice results in a pressure loss which reduces the high system pressure to atmospheric pressure.

28. The level control valve regulates the sludge level in the reactor. The electropneumatic throttle valve responds to an electric signal generated by the level detection system in the reactor.

29. The decant tank is essentially a gravity thickener. The sludge particles settle in the decant tank to a concentration of 20% or more. An overflow sidestream returns to the head of the plant. The BOD and SS content of the sidestream can have a significant impact on the operation of the plant.

30. In addition to the components already mentioned, steam is supplied to the heat treatment system by a boiler or a steam generator. Pure feed water is obtained by ion exchange treatment. Feed water is deaerated to remove most of the oxygen and other noncondensible gases.

31. Process control of the heat treatment system is influenced by four variables: temperature, pressure, feed concentration, and feed rate.

32. Temperature and pressure are closely related. Raising one raises the other. For example, increasing temperature will increase pressure, and vice versa.

33. The temperature and pressure in the reactor influence the extent and rate of treatment. Low levels of temperature and pressure cause incomplete treatment and necessitate long reaction time.

34. Higher levels of temperature and pressure cause more complete treatment and allow shorter reaction times.

35. But higher temperature and pressure cause high BOD and SS in the sidestream. BOD and SS are released by increased cell breakdown and greater solubility of cellular material.

36. Sludge concentration and feed rate influence reaction time. Lower concentration has the same effect as high feed rate. Both would result in short reaction time. Low feed rate means high concentration and would allow long reaction time.

37. Reaction time also influences the extent of treatment. Longer reaction times increase cell breakdown and can degrade the sidestream quality.

38. Increased dewaterability is the goal of conditioning by heat treatment. In general, dewaterability is increased by: higher temperatures, higher pressure, and longer reaction time.

39. However, if these variables are too high the sidestream quality may be unacceptable. Therefore, temperature, pressure, feed concentration, and feed rate must be carefully balanced and maintained to achieve the best dewaterability and acceptable sidestream quality.

40. Thus far we have discussed the use of heat treatment for conditioning. The heat treatment system can also reduce the organic content of sludge. This is often called wet air oxidation.

41. Wet air oxidation systems operate at much higher temperatures and pressures than systems designed to condition sludge.

42. The process destroys organic material by chemical oxidation. Oxygen and water, in addition to extremely high temperatures and pressures, are required for complete reduction of organics.

43. Compressed air is mixed with the feed sludge to supply the needed oxygen. This is the only major equipment difference between wet air oxidation and conditioning applications.

44. A relatively inert ash results from the wet air process. The ash is separated by solid separation technique. The liquid sidestream contains considerable BOD and SS and can have a serious impact on the plant.

45. Safety is a major concern with the heat treatment system because of the high temperatures and pressures involved. Treat all equipment as if it is very hot. Wear protective clothing.

46. Open and close valves slowly to avoid sudden fluctuations in pressure.

47. Tag and lock out electrical equipment before repair and maintenance. And keep all protective covers in place.

48. In reviewing the heat treatment process, recall that the major components are the heat exchanger and the reactor. Sludge picks up heat as it flows through the heat exchanger and enters the reactor. The hot sludge is cooled in the heat exchanger after it leaves the reactor.

49. Upstream components that prepare the sludge for treatment are the blend tank, the grinder, the high pressure pump, and the flow meter.

50. Downstream components are the orifice plate, the level control valve, and the decant tank.

51. The supernatant from the decant tank is a sidestream that can contain high BOD and SS and adversely affect plant operations.

52. Temperature, pressure, feed concentration, and feed rate are balanced to achieve increased dewaterability and acceptable sidestream quality.

53. The heat treatment process may be designed to condition sludge for further dewatering or for the reduction of solids by wet air oxidation.

WORKSHEET

Choose the best response to each question and place an "X" in front of your choice. There may be more than one correct answer.

1. The first full-scale, continuous flow system was placed in operation in

   ____ a. 1890

   ____ b. 1911

   __X__ c. 1964

   ____ d. 1970

2. The heat treatment utilizes which of the following processes to release water from sludge:

   __X__ a. hydrolysis

   ____ b. coagulation

   __X__ c. rapid temperature rise

   __X__ d. syneresis

3. What percentage of the solids are solubilized during the heat treatment process:

   ____ a. 0%

   ____ b. 10%

   __X__ c. 30%

   ____ d. 50%

4. Indicate, by numbering the following components in sequence, how sludge would pass through a heat treatment system.

   __6__ a. reactor

   __3__ b. high pressure pump

   __5__ c. heat-up side of heat exchanger

   __1__ d. blend tank

   __8__ e. orifice plates

   __4__ f. flow meter

   __2__ g. grinder

   __10__ h. decant tank

   __7__ i. cool-down side of heat exchanger

   __9__ j. level control valve

5. Which statement best describes the flow through the heat exchanger?

   X a. cool sludge is heated before the reactor.

   ___b. cool sludge is heated after the reactor.

   ___c. hot sludge transfers heat to treated sludge.

   ___d. hot sludge in cool before the reactor.

6. Steam and sludge enter the reactor

   ___a. together through two ports at the top.

   ___b. through a sluice-gate.

   ___c. under low pressure.

   X d. together through the standpipe.

7. What percent of the heat necessary to raise the sludge to operating temperature should be supplied by the heat exchanger?

   ___a. 25%

   ___b. 55%

   ___c. 65%

   X d. 85%

8. The level control valve

   ___a. maintains the proper operating level in the decant tank.

   X b. receives its signal from the level detector.

   ___c. can only be operated manually.

   ___d. is located prior to the high pressure pumps.

9. The high pressure in the reactor is reduced to atmospheric as the sludge passes through

   X a. the orifice plates

   ___b. the reactor

   ___c. the heat exchanger

   ___d. the decant tank

10. The deaerator

   ___a. removes air from the reactor.

   X b. removes O_2 from boiler feed water.

   ___c. removes O_2 from off-gas.

   ___d. adds air to control odor.

11. The off-gas system

_____ a. removes gas from the boiler.

_____ b. transfer gas to the reactor from the boiler.

__X__ c. transfers non-condensable gas from reactor to decant tank.

_____ d. is part of the heat high pressure pump.

12. The heat treatment process occurs in the

_____ a. boiler.

_____ b. heat exchanger.

_____ c. decant tank

__X__ d. reactor

13. Which of the following is not true?

_____ a. Heat treated sludge is denaterable to 40% solids.

__X__ b. The Porteous system uses compressed air.

_____ c. Heat treated sludge is sterile.

_____ d. The Porteous system uses direct heat in the form of steam.

14. Which of the following are true differences between the Porteous and Zimpro systems?

__X__ a. Zimpro uses compressed air, Porteous does not.

__X__ b. Zimpro is wet air oxidation, Porteous is conditioning.

_____ c. Porteous uses sludge coupled heat exchanger
Zimpro uses water coupled heat exchanger

_____ d. Porteous uses higher temperature and pressure than Zimpro.

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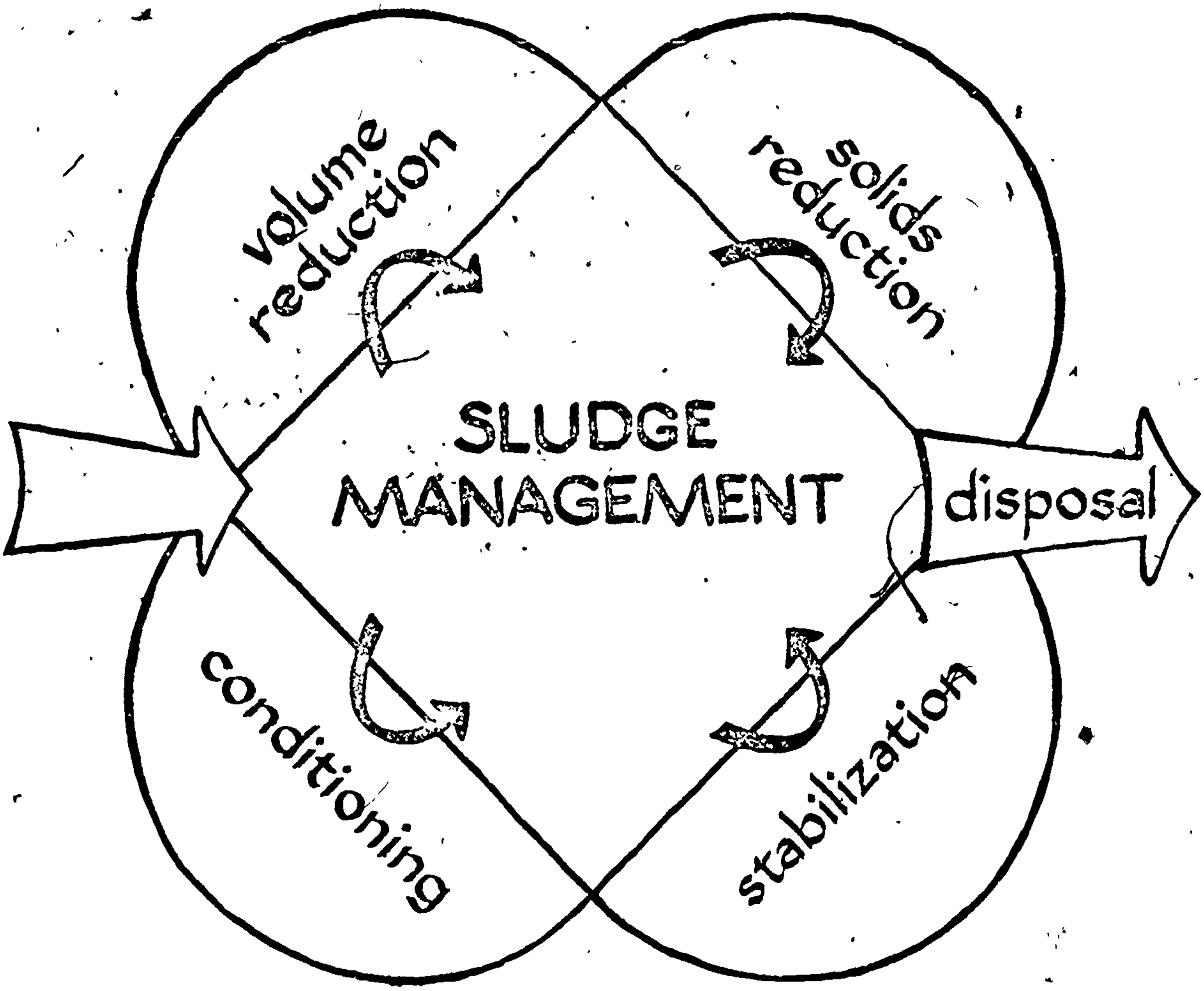
SLUDGE TREATMENT

and

DISPOSAL

COURSE # 166

HEAT TREATMENT



STUDENT WORKBOOK

Prepared by
Linn-Benton Community College
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SE039846

HEAT TREATMENT

Written by:
Herb Filer
Dale Broste
Envirotech Operating Services

Edited By:
John Carnegie, PhD.
Linn-Benton Community College

Instructional Design:
Priscilla Hardin
Corvallis, Oregon

Technical Consultant:
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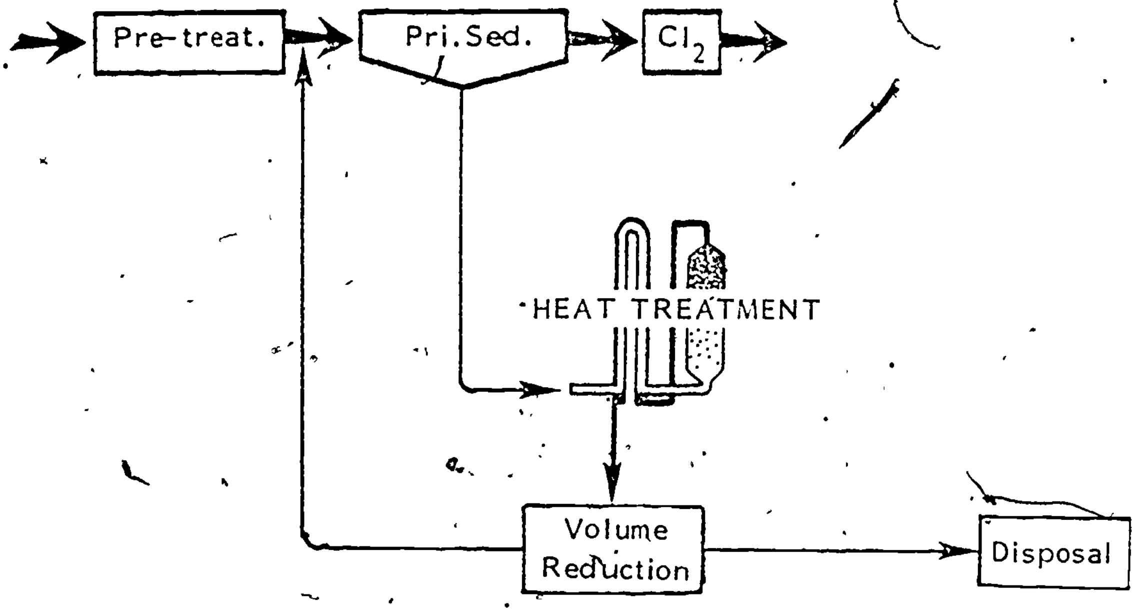
HEAT TREATMENT

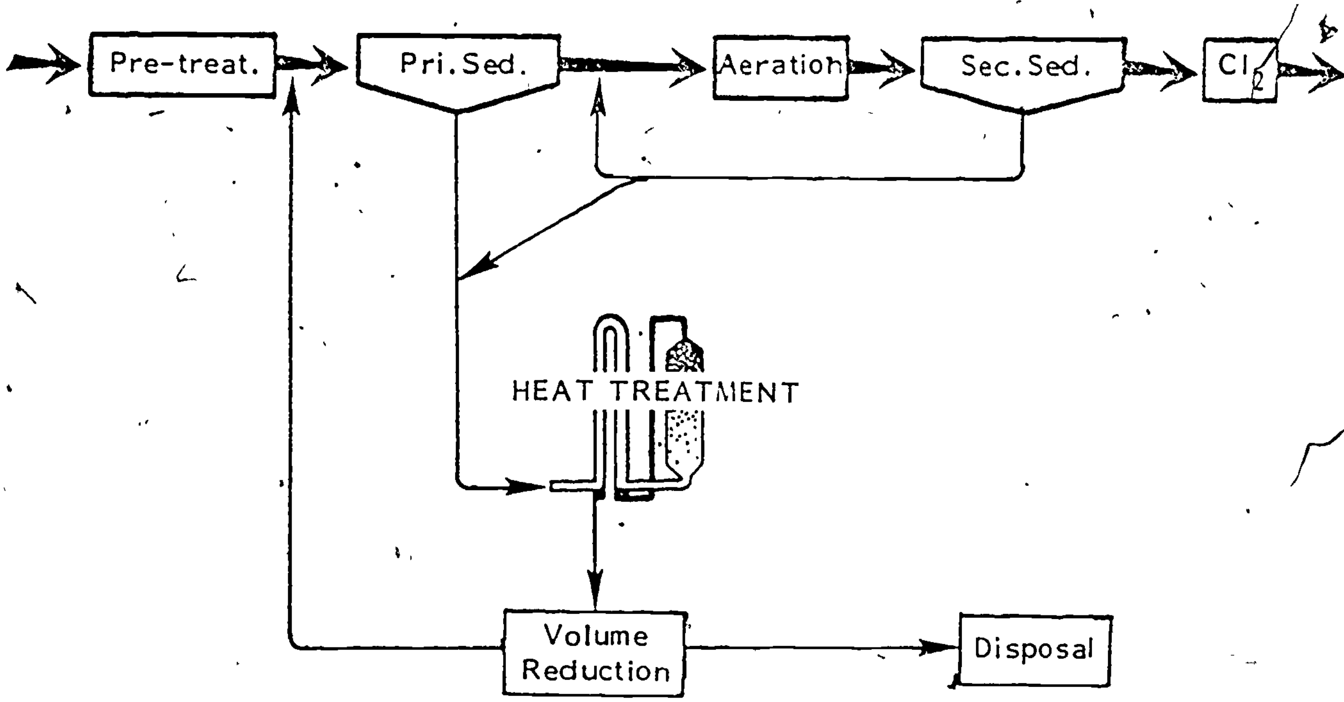
CONTENTS

PLANT FLOW DIAGRAMS

PRIMARY PLANT



SECONDARY PLANT



HEAT TREATMENT

OBJECTIVES

Upon completion of this lesson, you should be able to do the following:

1. Recall that the first full size, continuous flow systems were placed in operation in 1964.

2. Recall that syneresis and hydrolysis play a large role in releasing the water from sludge.

3. Be able to identify each of the following components of the heat treatment system and place them in the proper operational sequence.

    a) Blend tank

    b) Grinder

    c) High pressure pump

    d) Heat exchanger

    e) Reactor

    f) Orifice plates

    g) Decant tank

    h) Flow meter

    i) Level control valve

4. Recall that 85% of the heat necessary for operation comes from the heat exchanger.

5. Describe the purpose of the level control valve.

6. Describe the purpose of the orifice plates.

7. Recall the purpose of the deaerator.

8. Recall the purpose of the reactor off gas system.

9. Describe what happens in the reactor.

10. Be able to recall that heat treated sludge is dewaterable to 40% solids.

11. Describe safety precautions in the operation of a heat treat system.

12. Be able to state three differences between the Porteous and Zimpro systems.

HEAT TREATMENT

GLOSSARY

Coagulation - (koh-AG-yew-LAY-shun): (1) The agglomeration (clustering) of colloidal and finely divided suspended matter by the addition to the liquid of an appropriate chemical coagulant, by biological processes, or by other means. (2) The process of adding a coagulant and necessary other reacting chemicals.

Coalescence - The ability to grow or stick together.

Gels - A colloidal system in which liquid particles are dispersed in a solid phase.

Hydrolysis - (hy-DROL-uh-sis): A change in the chemical composition of matter produced by combination with water.

Syneresis - A process whereby true gels separate into their liquid and solids components under high pressure and temperature.

HEAT TREATMENT

HISTORY

*First experiments 1911

*First full-scale plant 1964

The heat treatment of sewage sludge is a derivative of attempts to make fuel briquettes from liquid peat in the late 1800's. The first actual experiments with sludge were begun about 1911. Porteous began work in 1920 and slowly developed and improved the process. It was not until 1964, however, that the first full-scale continuous flow plant was placed in operation.

GOAL: To Remove Water

*Bound Water

*Intracellular water

One of the major goals of sludge handling is to remove the water associated with sludge particles. Bound water and intracellular water are two types of water that make dewatering difficult.

CHEMICAL CONDITONERS

*Release Bound Water

*Don't release Intracellular Water

Chemical conditioning, by the process of coagulation can bring about the release of the bound water. Intracellular water, which is largely water contained in the body of the microorganisms in the sludge, is not effectively released with most types of chemical conditioning.

HEAT TREATMENT

*Releases both bound and intracellular water

In heat treatment both bound water and intracellular water are released. There are several physical and chemical reactions that take place that cause the release of this water. Individually, these reactions will only create a partial water release, but the combination of reactions causes a near total change in the characterisitcs of the sludge.

Rapid Temperature Change

*causes sludge to rupture

In the heat treatment process the sludge particles are subjected to a rapid temperature rise which causes the sludge particles and microbial cells to rupture releasing intracellular water. Without this rapid temperature change, the cells would essentially cook and eventually dissolve, and rather than removing the solids as sludge, they would be made soluble and returned to the plant. Up to 30% of the solids are solutionized during the heat treatment process.

SYNERESIS
*breakdown of gel under
*high temperature & pressure

Syneresis refers to a process whereby true gels will separate into their liquid and solids components under high pressure and temperature. The sludge particles and bound water do act much like a true gel. Under high temperature and pressure, the increased molecular activity causes the particles to collide with each other, resulting in a breakdown of the gel-like structure and release of bound water. This is syneresis.

HYDROLYSIS
*water released by chemically combining

The chemical process of hydrolysis also helps release water from sludge. Hydrolysis is a reaction in which water molecules combine with other molecules. In the process water is used up. Water combines with dissolved compounds, surrounding the sludge and with protein material in the sludge. This in turn releases water and results in coalescence of the particles.

HEAT TREATMENT SYSTEMS
*Porteous
*Zimpro

There are two popular heat treatment systems in use at the present time; the Porteous process and the Zimpro process.

We will discuss the Porteous system first and then look at the similarities and difference in the Zimpro system.

Process Flow
*blend tank
*high pressure pump
*flow meter
*heat-up side
*reactor
*cool-down side
*orifice plates
*level control valve
*decant tank

The heat treatment process is a continuous flow system beginning with a blend tank, through a grinder and a high pressure pump and to a flow meter. The sludge then proceeds through the heat-up side of the heat exchanger and into the reactor, through the cool-down side of the heat exchanger, through a series of orifice plates and level control valve to the decant tank.

BLEND TANK

*collecting & mixing
*6 hours holding
*surge control
*covered

As sludge is pumped from the various parts of the plant, it is collected and mixed in the blend tank. The tank is large enough to hold about 6 hours supply to the heat treatment system. This allows for large fluctuations in sludge coming to the tank while maintaining a continuous flow through the system. The tank is usually covered to reduce odor problems.

GRINDER

*reduce size - ¼" or less
*prevents plugging, damage

The sludge grinder is usually an industrial version of the household garbage grinder. Particle size is reduced to 1/4" or less to prevent plugging of heat exchanger tubes and damage to system valves.

HIGH PRESSURE PUMP

*Positive displacement
*Raises sludge to operating pressure

After the grinder the high pressure pump raises the sludge pressure to system operating pressure. To obtain the high pressure required by the system, positive displacement pumps, such as progressive cavity, multi-stage piston or equivalent, are required.

FLOW METER

*magnetic coupled

A magnetic coupled flow meter is usually used to monitor the flow of sludge through the system.

HEAT EXCHANGER

*heat-up
*cool-down
*after-cooler

The heat exchanger is actually 2 or 3 separate heat exchangers. The heat-up side preheats the sludge prior to its entering the reactor. The cool-down side cools the sludge leaving the reactor. The after-cooler further cools the heated sludge.

Heat Exchangers-liquid coupled
*tube in tube counter flow
*provides 85% of heat

The heat exchangers are liquid coupled and tube in tube counterflow. Sludge flows through the inner tube and water through the surrounding outer tube. Heat is transferred from the sludge to the water or vice versa. The exchanger should provide 85% of the heat needed to raise the temperature of the incoming sludge.

REACTOR
*Live steam injected
*Rapid temperature increase
*Constant flow through
*1 hour detention time

After being preheated, the sludge enters the reactor where the actual heat treatment process occurs. Sludge enters through a center stand pipe and nozzle where live steam is injected. The sludge experiences a rapid increase in temperature at this point. At the same time, an equal amount of sludge is being discharged from two ports on the bottom of the reactor. The high pressure reactor vessel is sized to have a detention time of about one hour.

REACTOR
*level detector
*off-gas system

The sludge level in the reactor is measured by a nuclear level detector. The detector, using Cesium 137 as a radioactive source, measures change in density between the liquid and gas levels and sends a signal to a receiver on the exterior of the reactor.

The reactor is also equipped with an off gas system. To prevent a build-up of non-condensable gases in the reactor, the gases are piped out of the reactor to the decant tank.

ORIFICE PLATES
*Reduces pressure

After leaving the reactor and passing through the cool-down side of the heat exchanger, the sludge goes through a series of orifice plates. The small size of these orifices result in a progressive reduction of high system pressure to atmospheric pressure.

LEVEL CONTROL VALVE

*electro-pneumatic

*signal from level detector

*automatic or manual

The level control valve is an electro-pneumatic-operated throttle valve. The electrical operating signal for the valve is generated by the level detection system. The electrical signal is converted to a pneumatic signal which automatically positions the valve. The valve can also be operated manually either by remote electrical signal or by hand.

DECANT TANK

*20% solids in underflow

*sidestream overflow-load

Sludge finally passes to a decant tank which acts as a gravity thickener. Solids content in the tank underflow can be 20% or more. The overflow stream can have a significant impact on the head of the plant.

BOILERS

*boiler or steam generator

*treated feed water

*deaerated feed water

Steam to the heat treatment system is supplied by a boiler or a steam generator. Pure feed water is supplied by ion exchange treated water. Feed water is deaerated to remove most of the O_2 and other non-condensable gases.

CONTROL VARIABLES

*Temperature

*Pressure

*Feed Concentration

There are three physical variables that control the performance of the heat treatment units: temperature, pressure, and feed solids concentrations.

Pressure and Temperature Effect:

*reaction time possible

*degree of cell breakdown

*quality of sidestream

The extent and rate of treatment are determined by reactor pressure and temperature. Shorter reaction time and more complete treatment are possible at higher pressures and temperature. Pressure and temperature also affect sidestream quality. Higher pressure and temperatures result in more cell breakdown, greater solubility of cellular material and, therefore, higher BOD in sidestream.

Increase Holding Time:

*degrades sidestream

Increasing holding time in reactor will increase cell breakdown and degrade the sidestream quality. Holding time in the reactor is controlled by flow rate and sludge solids concentration.

Dewaterability increased by:
- *higher temperature
- *higher pressure
- *longer reaction time

Higher temperature and pressures, and longer reaction time generally increase dewaterability, however. Therefore, all three operational variables must be carefully balanced and maintained to get the best dewaterability without unacceptable sidestream.

BALANCE VARIABLES

SAFETY
- *hot equipment
- *protective clothing
- *operate valves slowly
- *tag and lock out electrical
- *protective covers in place

The heat treatment system is a high energy system, that is, high temperatures and pressures. Treat everything as though it were very hot. Wear protective clothing. Open and close all valves slowly. De-energize electrical circuits before repairs or maintenance and keep all protective covers in place.

PORTEOUS SYSTEM
- *Non-chemical conditioning
- *40% solids possible with further dewatering
- *sterile sludge produced

In summary the Porteous heat treatment system provides a non-chemical means to increase the dewaterability of sludge. Heat treated sludge can successfully further dewater sludge solids to 40% or higher and produces a sterile end product, reducing the health hazards encountered in sludge handling.

ZIMPRO SYSTEM
- *Wet air oxidation
- *Reduction of organic solids

The Zimpro treatment system is referred to as a wet air oxidation process. Whereas the objective of the Porteous process is conditioning for further dewatering,the objectives of the Zimpro process are comparable to conventional flame combustion, i.e. reduction of organic material.

Essentially any substance capable of burning can be oxidized in the presence of liquid water at high temperature and pressures. The process is carried out using essentially the same

ZIMPRO SYSTEM

*USES SAME EQUIPMENT EXCEPT:

Compressed air

Sludge-coupled heat exchanger

higher temperature & pressure

equipment as the Porteous process except that compressed air is added to the sludge prior to entering the heat-up side of the heat exchanger. The heat exchanger is of the sludge coupled type. The system is operated at a higher temperature and pressure.

	Temp	Pressure
Porteous	350-400°F	150-300 psig
Zimpro	450-550°F	1200 psig

HEAT TREATMENT

References

Required Reading

Student Text "Heat Treatment", EPA Course #166.

Reference Reading

Student Text "Sludge Characteristics" and "Sludge Conditioning", EPA Course #166.

Process Design Manual for Sludge Treatment and Disposal, USEPA, September, 1979, EPA 625/1-79-011.

HEAT TREATMENT

WORKSHEET

Choose the best response to each question and place an "X" in front of your choice. There may be more than one correct answer.

1. The first full-scale, continuous flow system was placed in operation in

_____ a. 1890

_____ b. 1911

_____ c. 1964

_____ d. 1970

2. The heat treatment utilizes which of the following processes to release water from sludge:

_____ a. hydrolysis

_____ b. coagulation

_____ c. rapid temperature rise

_____ d. syneresis

3. What percentage of the solids are solubilized during the heat treatment process:

_____ a. 0%

_____ b. 10%

_____ c. 30%

_____ d. 50%

4. Indicate, by numbering the following components in sequence, how sludge would pass through a heat treatment system.

_____ a. reactor

_____ b. high pressure pump

_____ c. heat-up side of heat exchanger

_____ d. blend tank

_____ e. orifice plates

_____ f. flow meter

_____ g. grinder

_____ h. decant tank

_____ i. cool-down side of heat exchanger

_____ j. level control valve

5. Which statement best describes the flow through the heat exchanger?

_____a. cool sludge is heated before the reactor.

_____b. cool sludge is heated after the reactor.

_____c. hot sludge transfers heat to treated sludge.

_____d. hot sludge in cool before the reactor.

6. Steam and sludge enter the reactor

_____a. together through two ports at the top.

_____b. through a sluice-gate.

_____c. under low pressure.

_____d. together through the standpipe.

7. What percent of the heat necessary to raise the sludge to operating temperature should be supplied by the heat exchanger?

_____a. 25%

_____b. 55%

_____c. 65%

_____d. 85%

8. The level control valve

_____a. maintains the proper operating level in the decant tank.

_____b. receives its signal from the level detector.

_____c. can only be operated manually.

_____d. is located prior to the high pressure pumps.

9. The high pressure in the reactor is reduced to atmospheric as the sludge passes through

_____a. the orifice plates

_____b. the reactor

_____c. the heat exchanger

_____d. the decant tank

10. The deaerator

_____a. removes air from the reactor.

_____b. removes O_2 from boiler feed water.

_____c. removes O_2 from off-gas.

_____d. adds air to control odor.

11. The off-gas system

_____a. removes gas from the boiler.

_____b. transfer gas to the reactor from the boiler.

_____c. transfers non-condensable gas from reactor to decant tank.

_____d. is part of the heat high pressure pump.

12. The heat treatment process occurs in the

_____a. boiler.

_____b. heat exchanger.

_____c. decant tank

_____d. reactor

13. Which of the following is not true?

_____a. Heat treated sludge is denaterable to 40% solids.

_____b. The Porteous system uses compressed air.

_____c. Heat treated sludge is sterile.

_____d. The Porteous system uses direct heat in the form of steam.

14. Which of the following are true differences between the Porteous and Zimpro systems?

_____a. Zimpro uses compressed air, Porteous does not.

_____b. Zimpro is wet air oxidation, Porteous is conditioning.

_____c. Porteous uses sludge coupled heat exchanger
Zimpro uses water coupled heat exchanger

_____d. Porteous uses higher temperature and pressure than Zimpro.